Developments on Chemical Looping Combustion of Biomass

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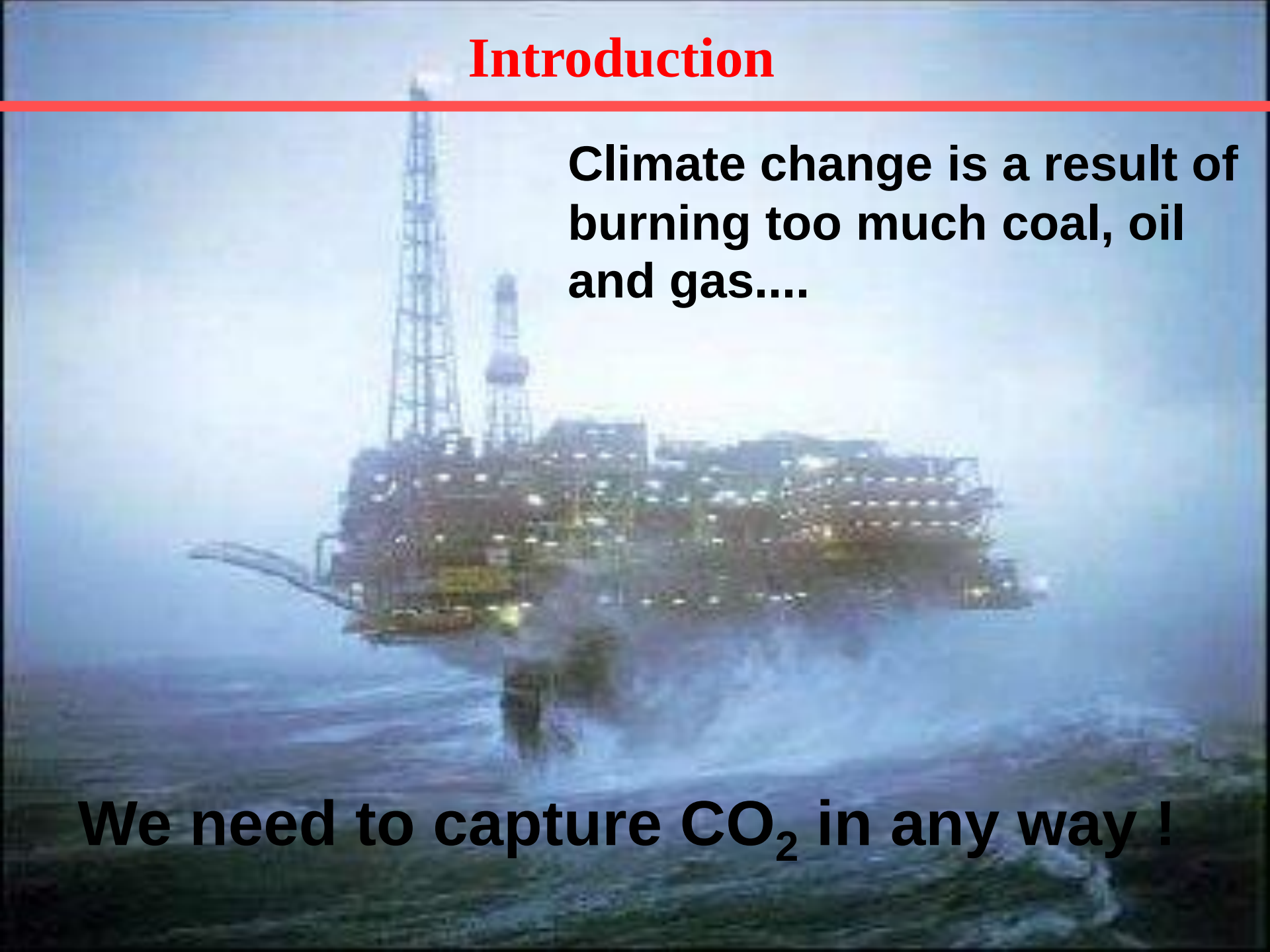
Overview

- Introduction
- Technical approach
- Experiments on chemical looping combustion of biomass
- Conclusions

Introduction



Climate change is a result of burning too much coal, oil and gas....

We need to capture CO_2 in any way !

Introduction

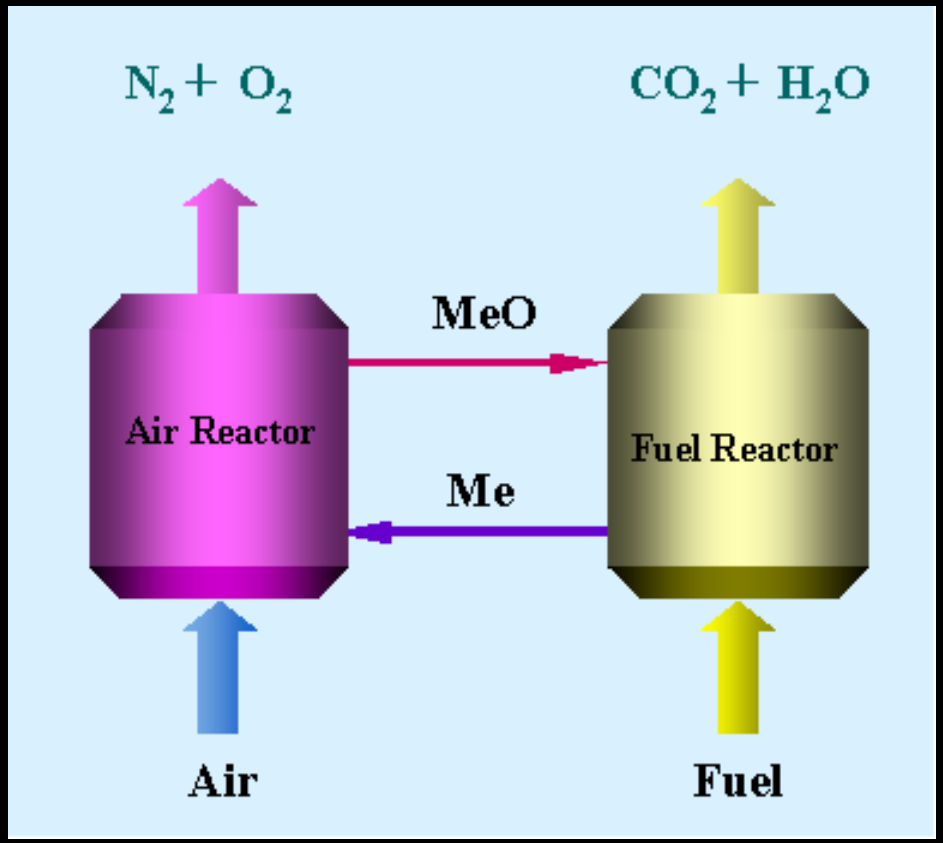
CCS is the world's best chance

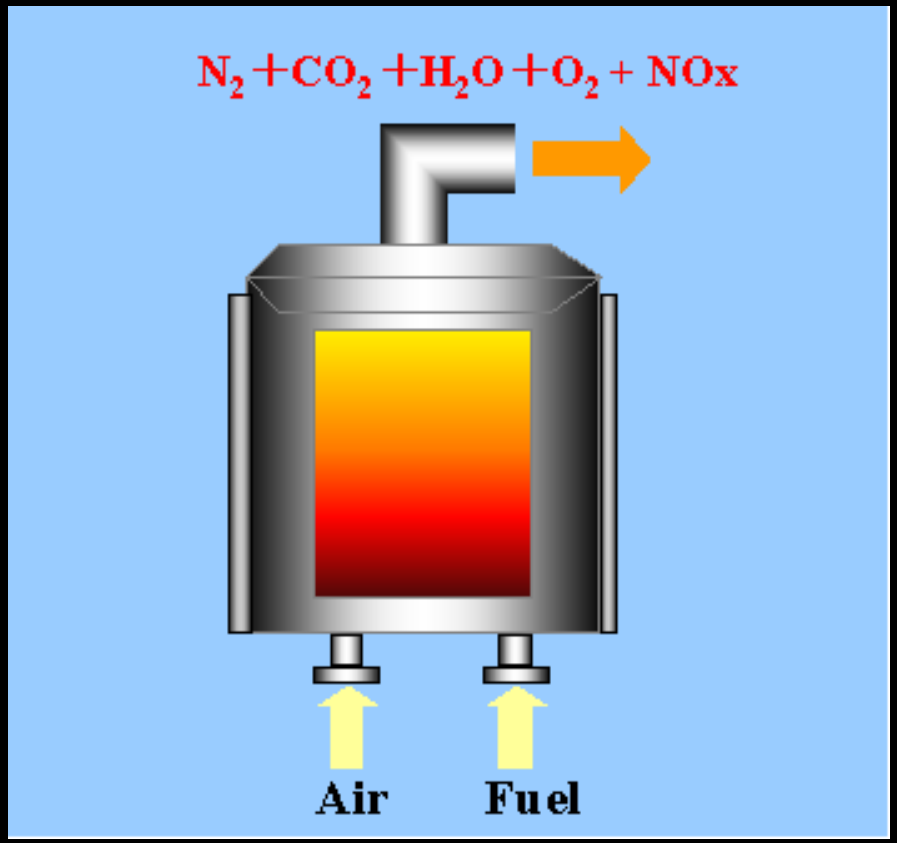
to have a major & immediate impact on CO_2 emission reduction

Introduction

- Biomass is renewable energy with **zero** CO_2 emission
- A way to capture CO_2 from biomass ?
- If so, a quick way to reduce CO_2 content in the atmosphere

Introduction



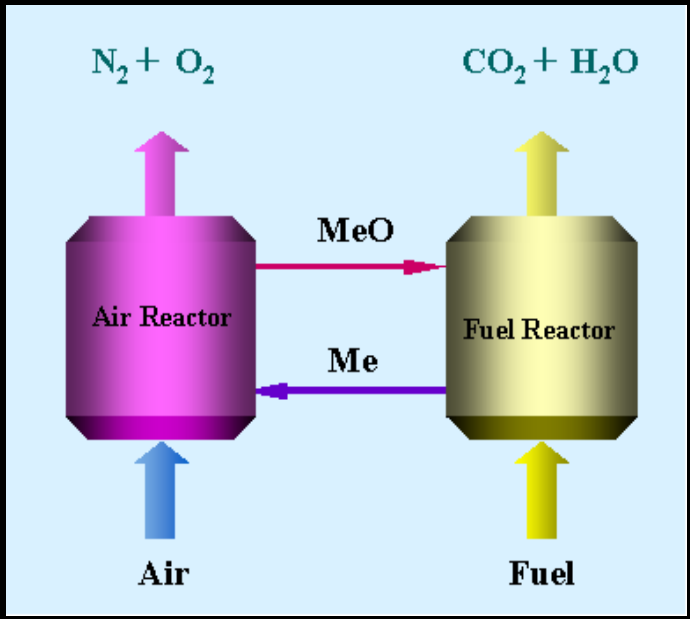


Chemical looping combustion **Normal combustion**

- **Chemical Looping Combustion is an indirect combustion technology by use of oxygen carrier. It can be used for CO2 capture in power generation process.**

Introduction

Reactions



Oxidation

$$2Me_xO_{y-1} + O_2 \rightarrow 2Me_xO_y$$

Reduction

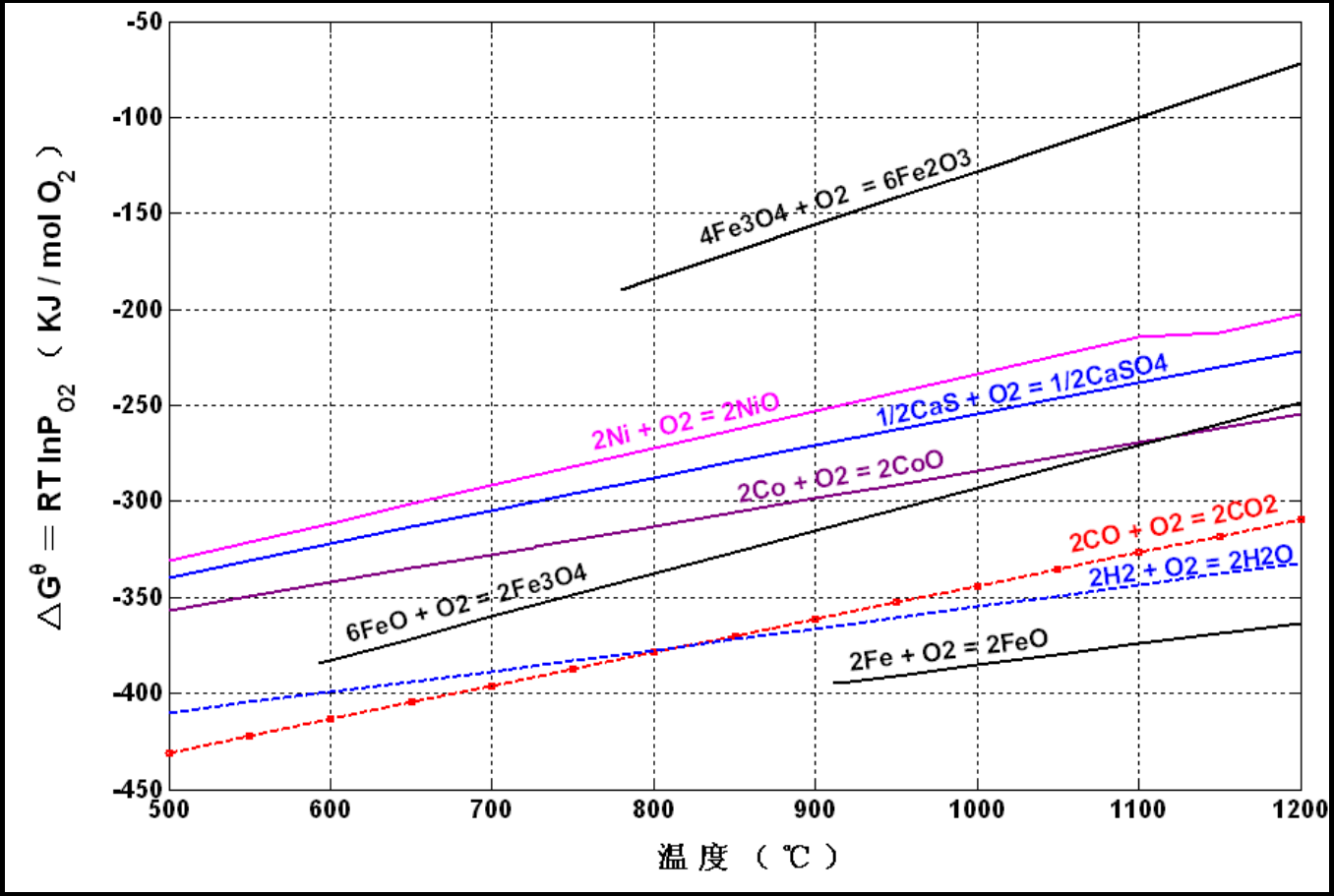
$$(2n+m)Me_xO_y + C_nH2_m \rightarrow (2n+m)Me_xO_{y-1} + nCO_2 + mH_2O$$

Sum

$$(n + \tfrac{1}{2}m)O_2 + C_nH_{2m} \rightarrow nCO_2 + mH_2O$$

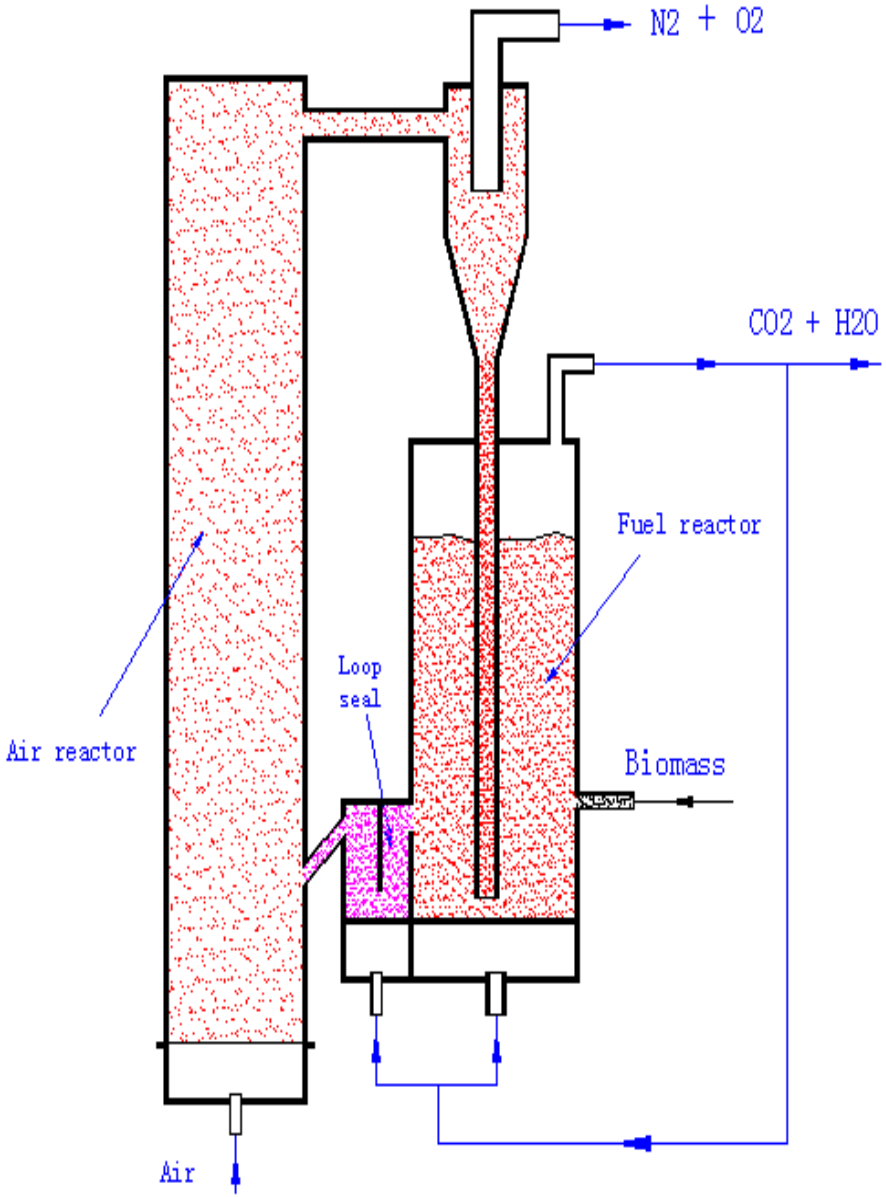
Technical approach

Reactivity of Oxygen carrier



Laihong Shen, Min Zheng, Jun Xiao, Rui Xiao.
A mechanistic investigation of a calcium-based oxygen carrier for chemical looping combustion.
Combustion and Flame, 2008.04.017 (In pressed)

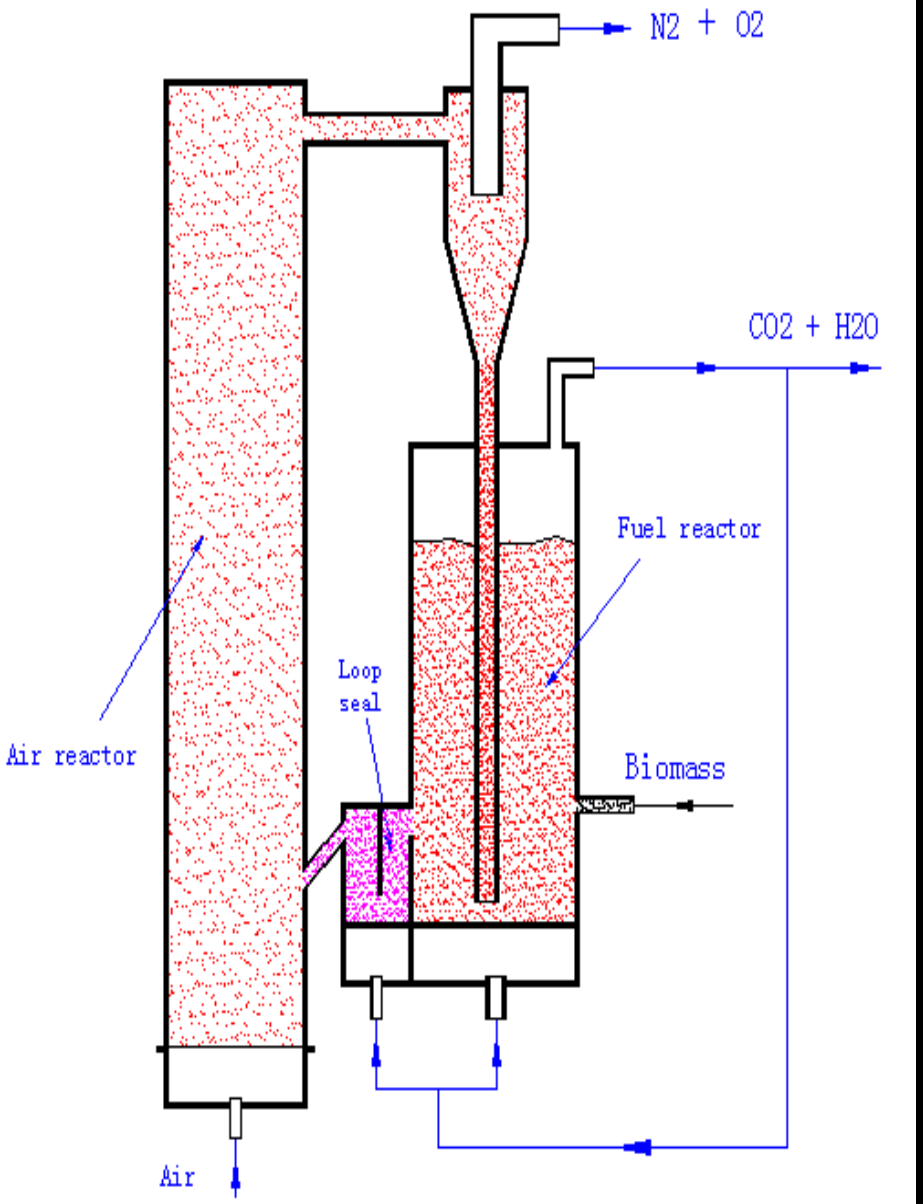
Technical approach



1. **Air reactor**
   (circulating fluidized bed)
2. **Fuel reactor**
   (bubbling fluidized bed)
3. **Loop seal**
   (moving bed)

Laihong Shen, Yang Gao, Jun Xiao. Simulation of hydrogen production from biomass gasification in interconnected fluidized beds. Biomass and bioenergy 2008, 32:120-127.

Technical approach



Fuel reactor

- **Biomass pyrolysis**

$$H_2 + CO + CO_2 + CH_4 + C + Tar$$

- **Biomass gasification**

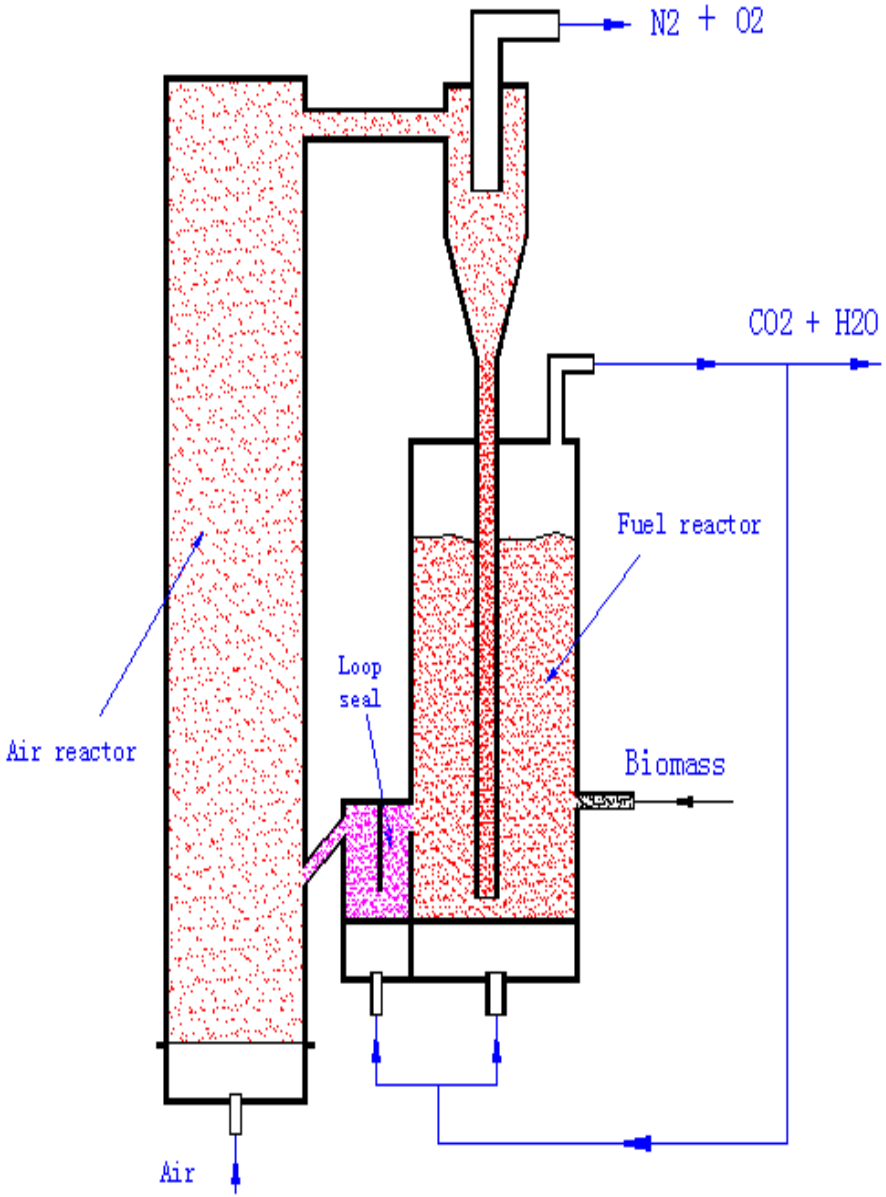
$$C + CO_2 \rightarrow 2CO$$

$$C + H_2O \rightarrow CO + H_2$$

$$CO + H_2O \rightarrow CO_2 + H_2$$

$$Tar + H_2O \xrightarrow{Ni\ Catalyst} CO + CO_2 + H_2$$

Technical approach



Fuel reactor

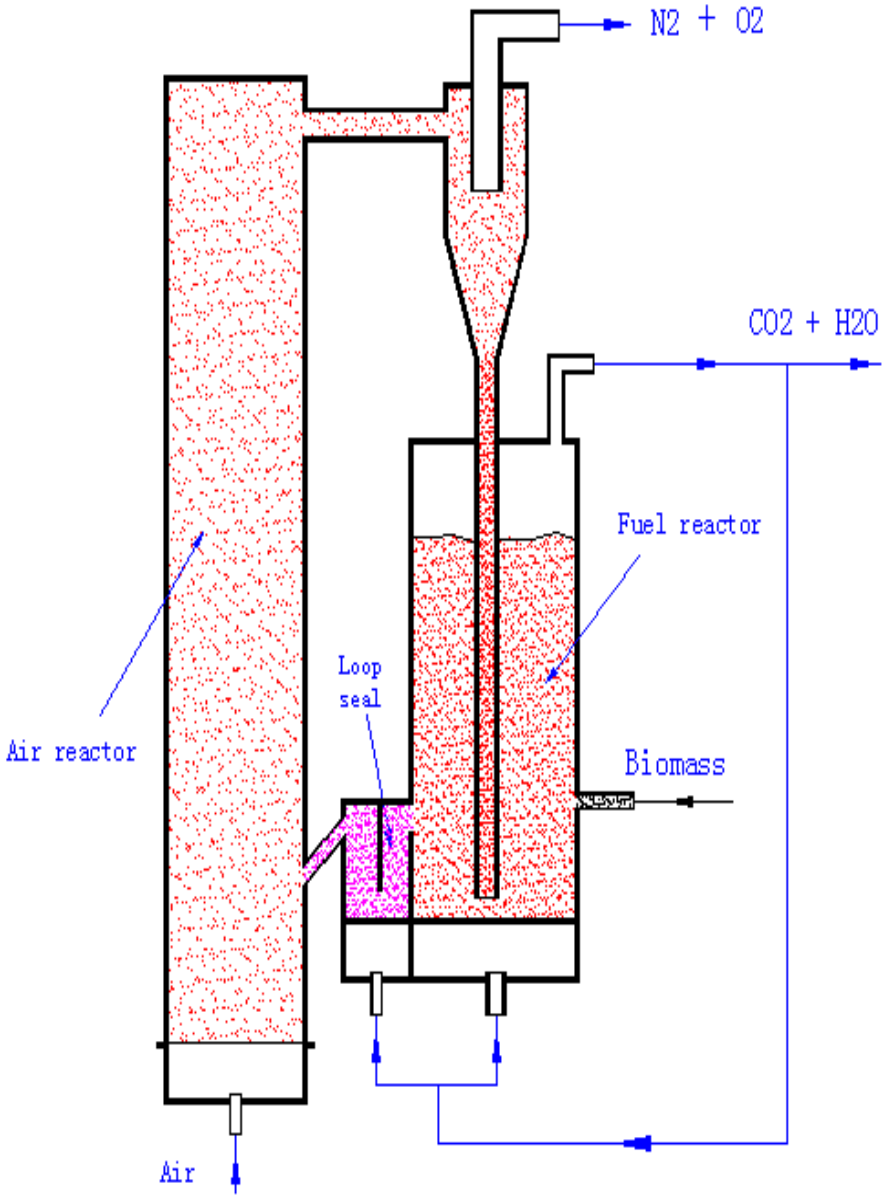
- **NiO reduction**

$$NiO + CO \rightarrow Ni + CO_2$$

$$NiO + H_2 \rightarrow Ni + H_2O$$

$$4NiO + CH_4 \rightarrow Ni + CO_2 + 2H_2O$$

Technical approach



Air reactor

- **Ni oxidization**

$$2Ni + O_2 \rightarrow 2NiO$$

Technical approach

Parameters

Air reactor

dia. 50 mm, H 2000 mm

Fuel reactor

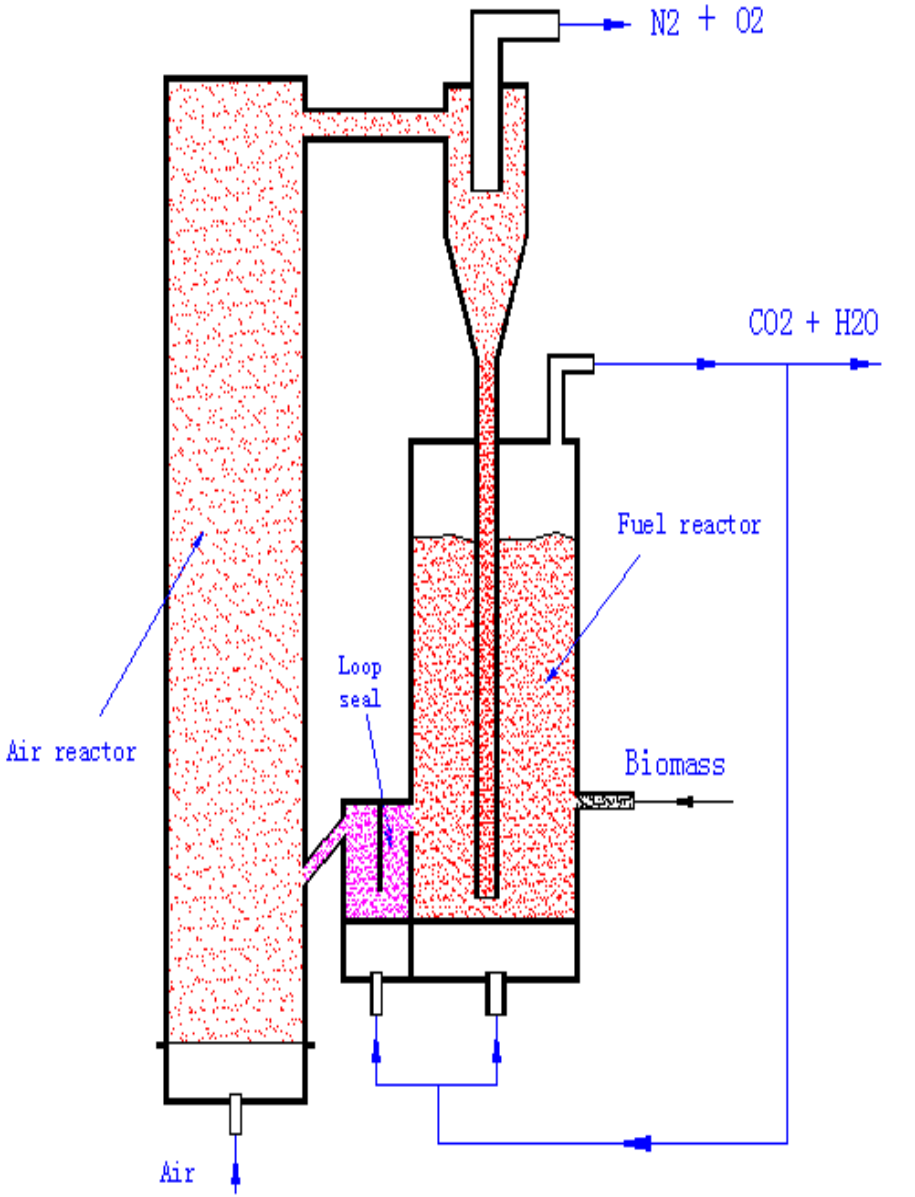
230 X 40 mm^2, H 1500 mm

Temperature

Air reactor 850 – 1050 ℃

Fuel reactor 700 – 950 ℃

Technical approach



Parameters

Biomass : Pine wood

prox. & ultimate analysis *(wt.%)*

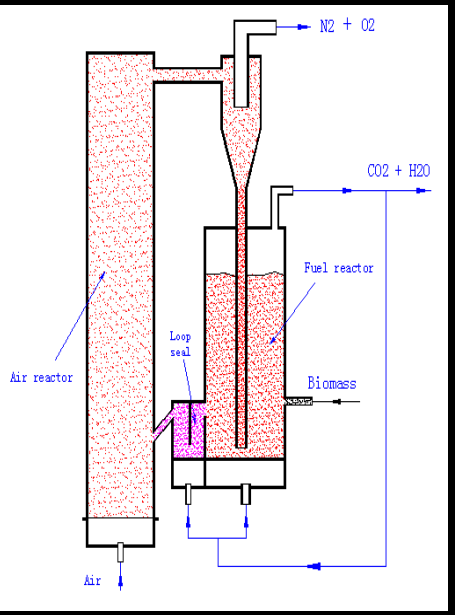
Moisture	8.5	C	36.57
Fixed Carbon	17.91	H	4.91
Volatile	64.98	O	40.70
Ash	8.61	N	0.5
		S	0.14
		Cl	1.55

Low heating value (MJ/kg) 14.60

mean diameter : 2 mm

feed rate : 0 – 2 kg / h

Technical approach



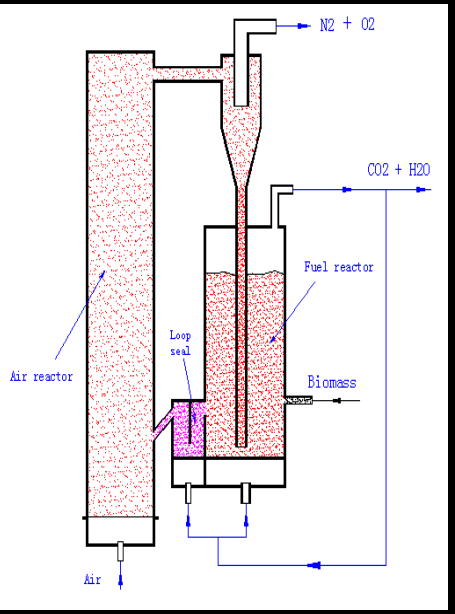
Freeze-granulated Ni / NiO particles used in a test unit

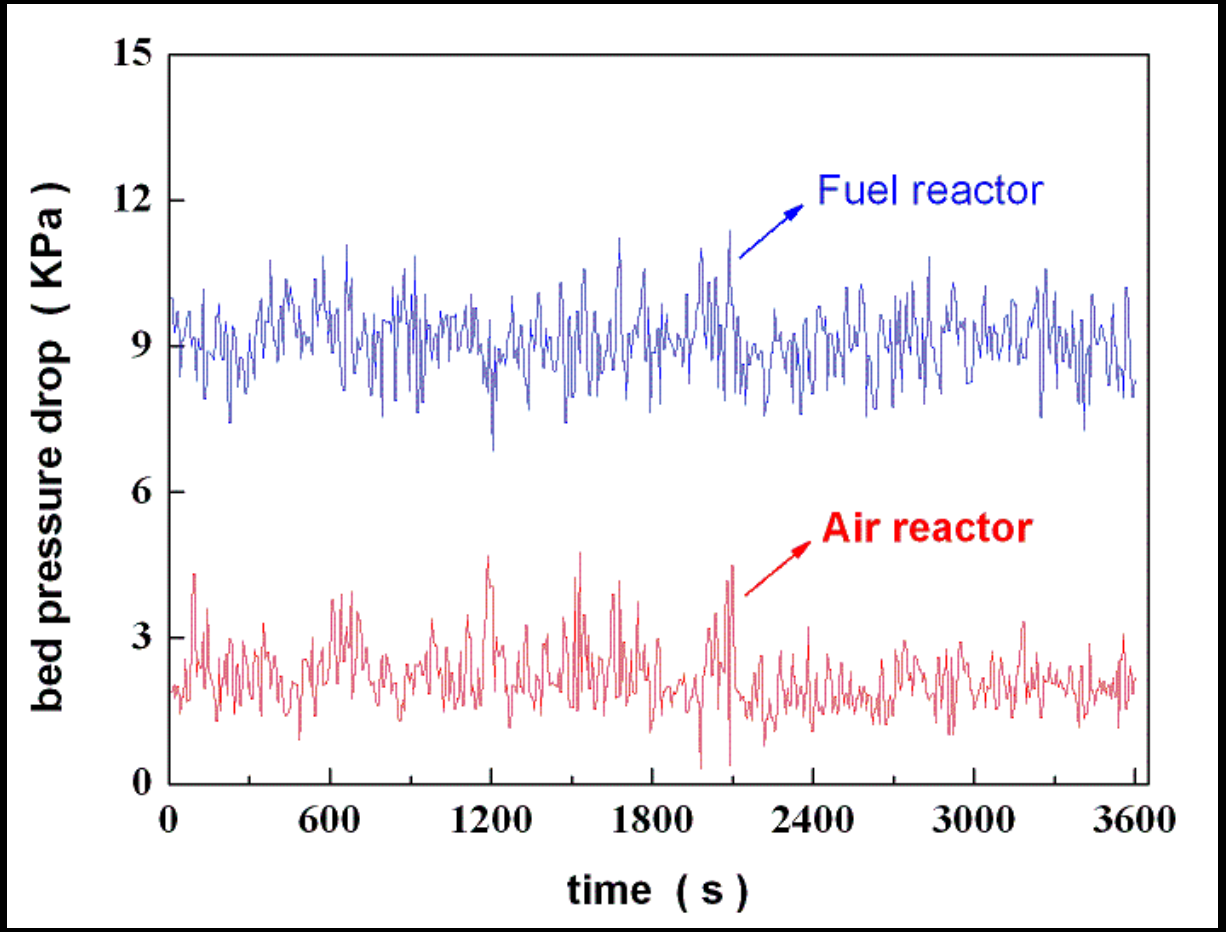
Oxygen Carrier :

32.7% NiO - 67.3% Al_2O_3

mean diameter : 0.3 mm

Experiments on chemical looping combustion of biomass





Typical time series of bed pressure drops
both in the fuel reactor and in the air reactor

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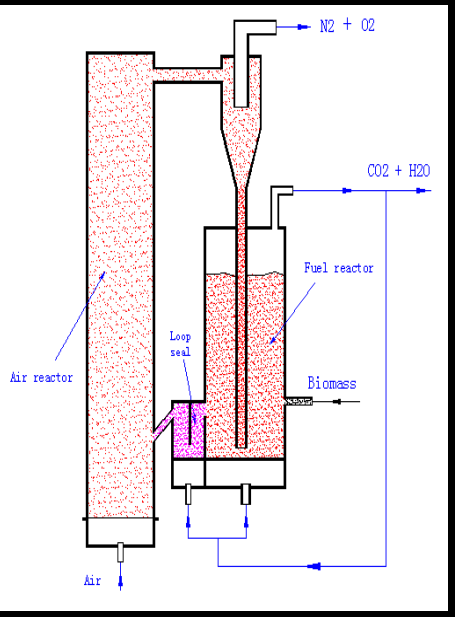
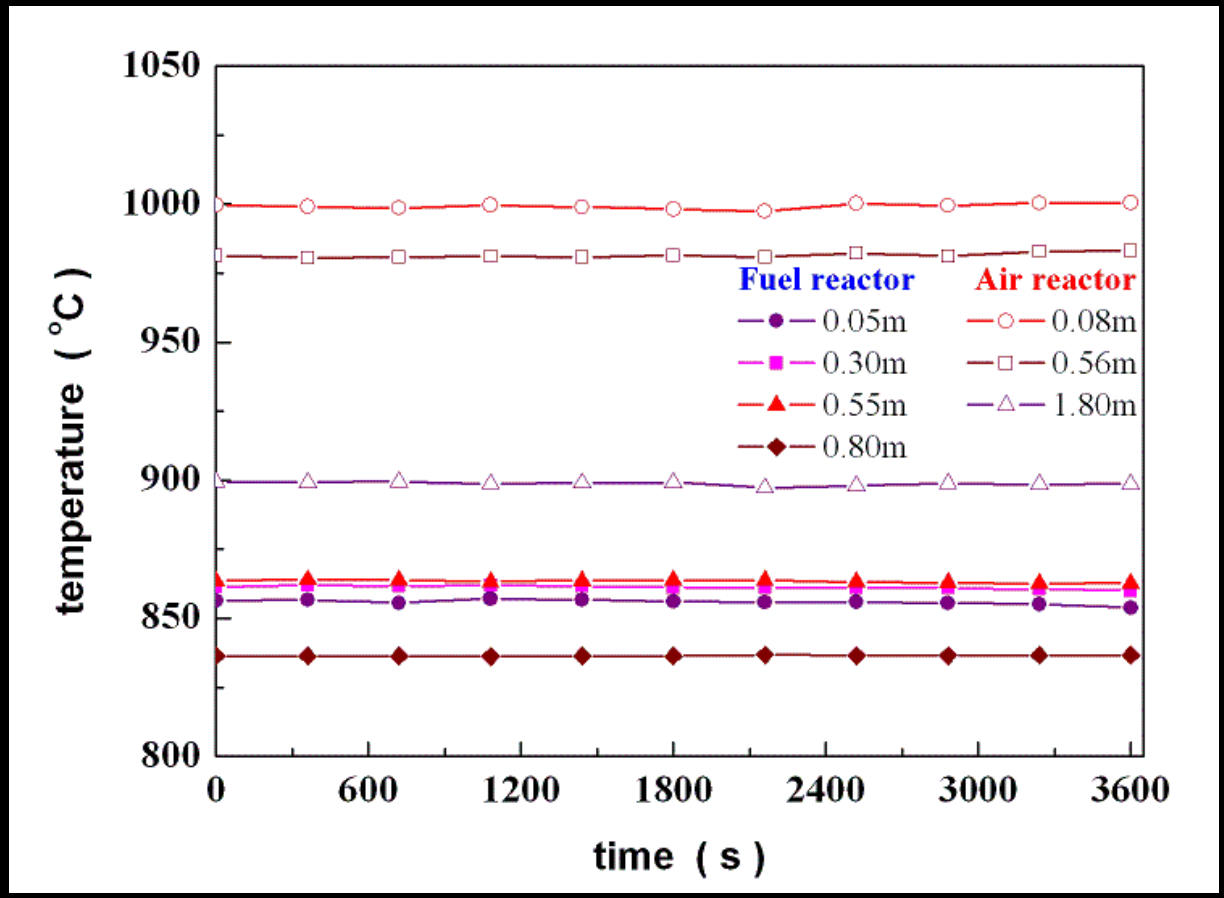
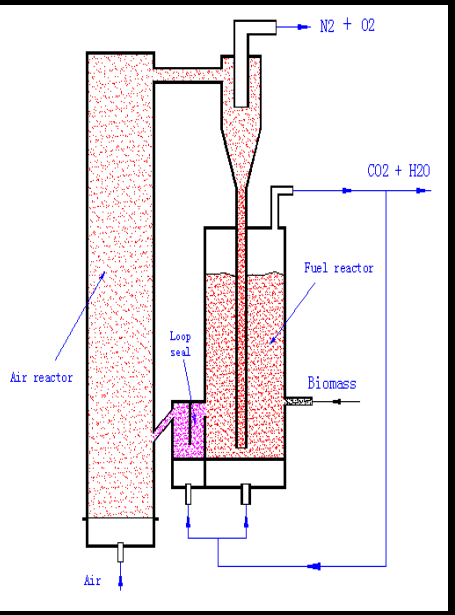
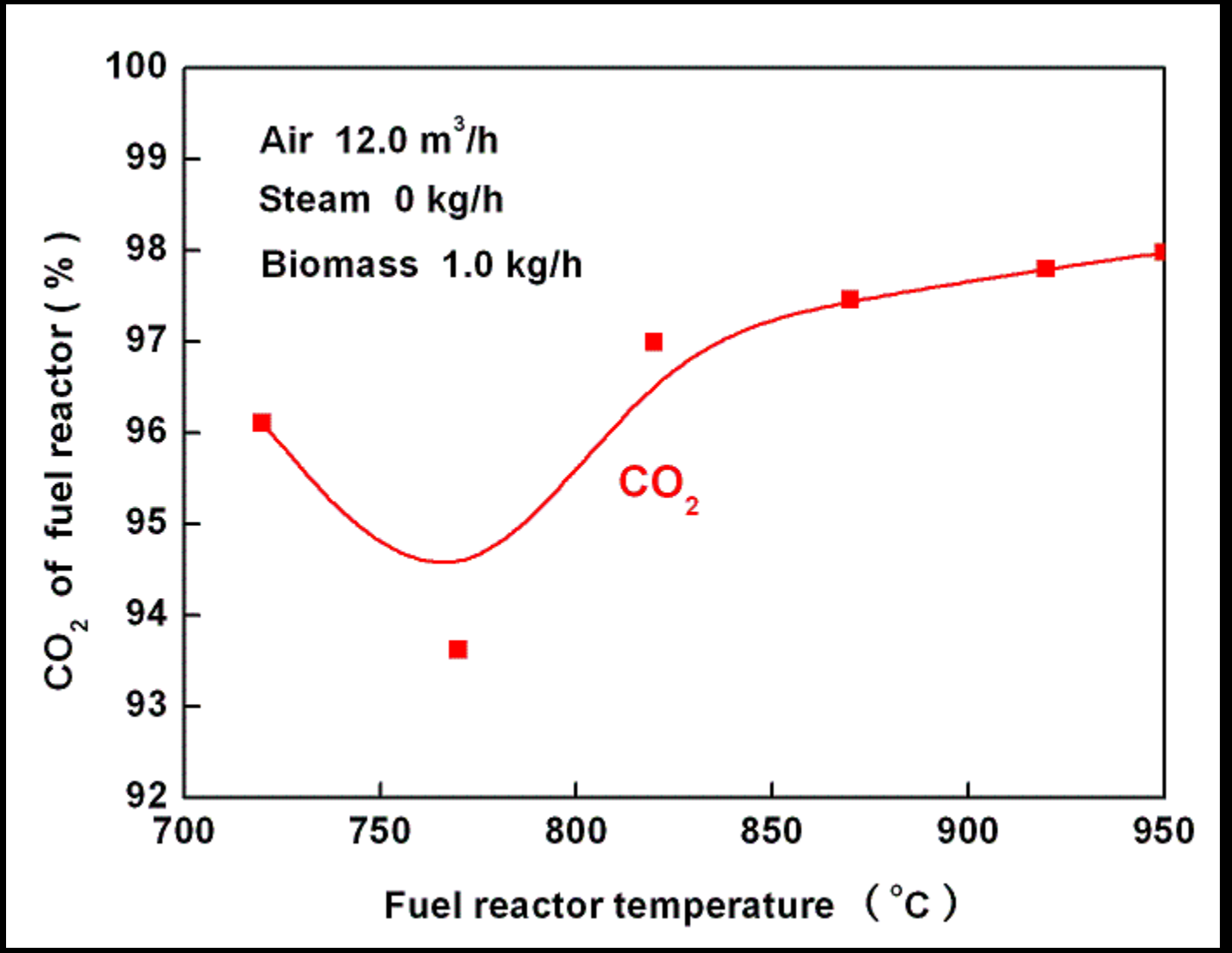




Typical time series of temperature
both in the fuel reactor and in the air reactor

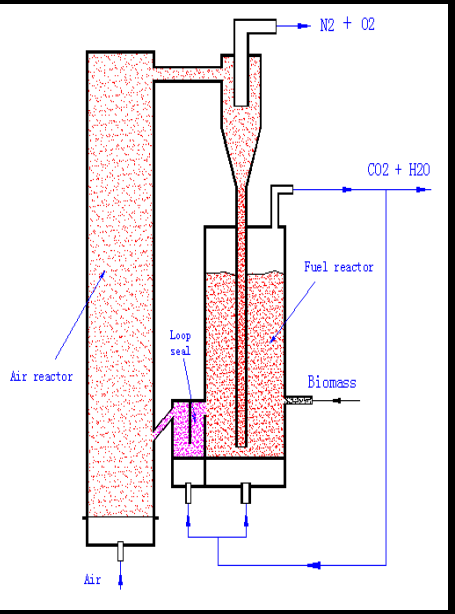
Experiments on chemical looping combustion of biomass

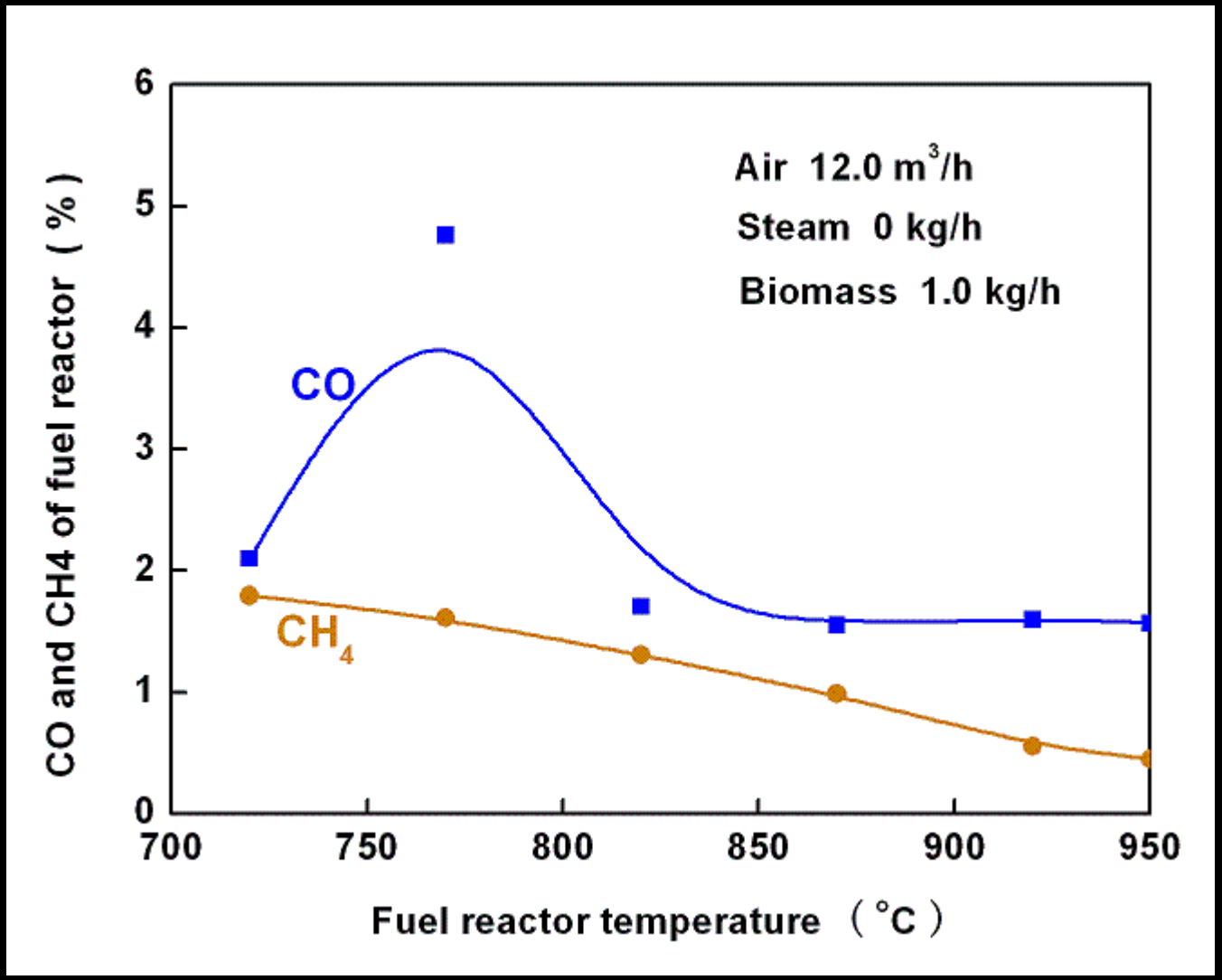




Effect of fuel reactor temperature

Experiments on chemical looping combustion of biomass





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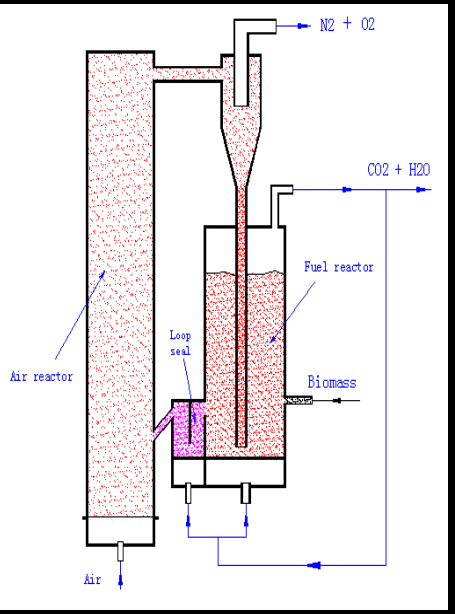
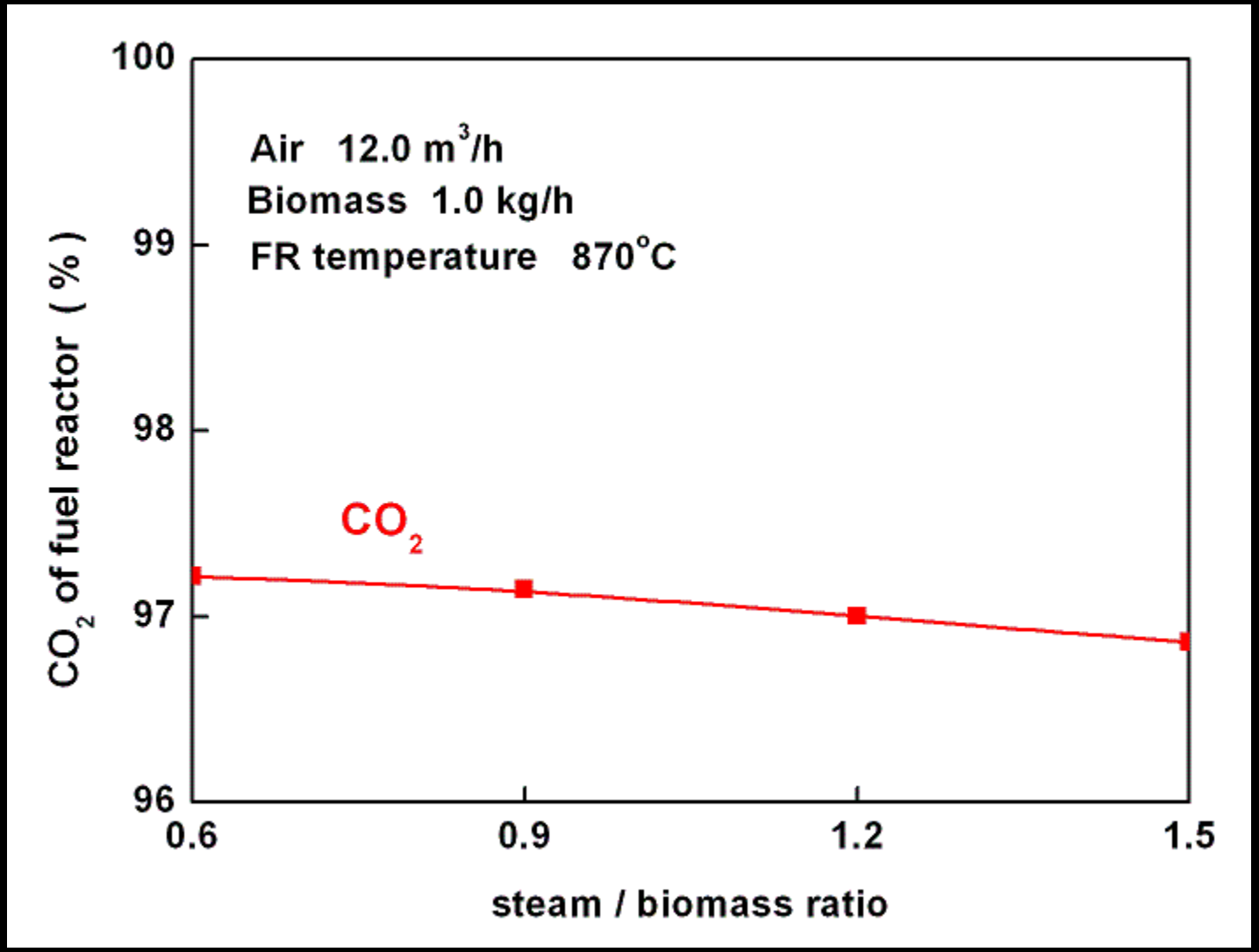
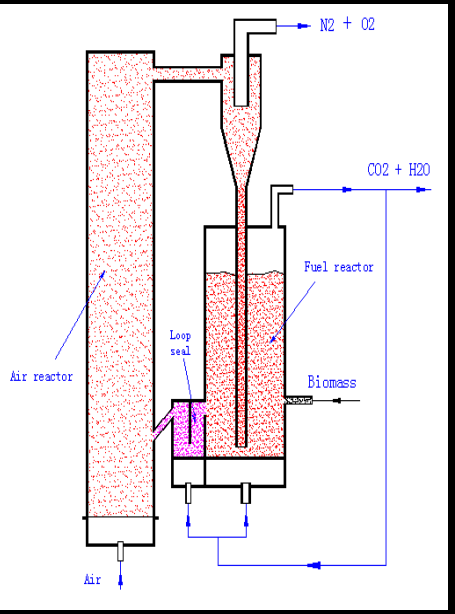


FR : fuel reactor



Effect of steam / biomass ratio

Experiments on chemical looping combustion of biomass



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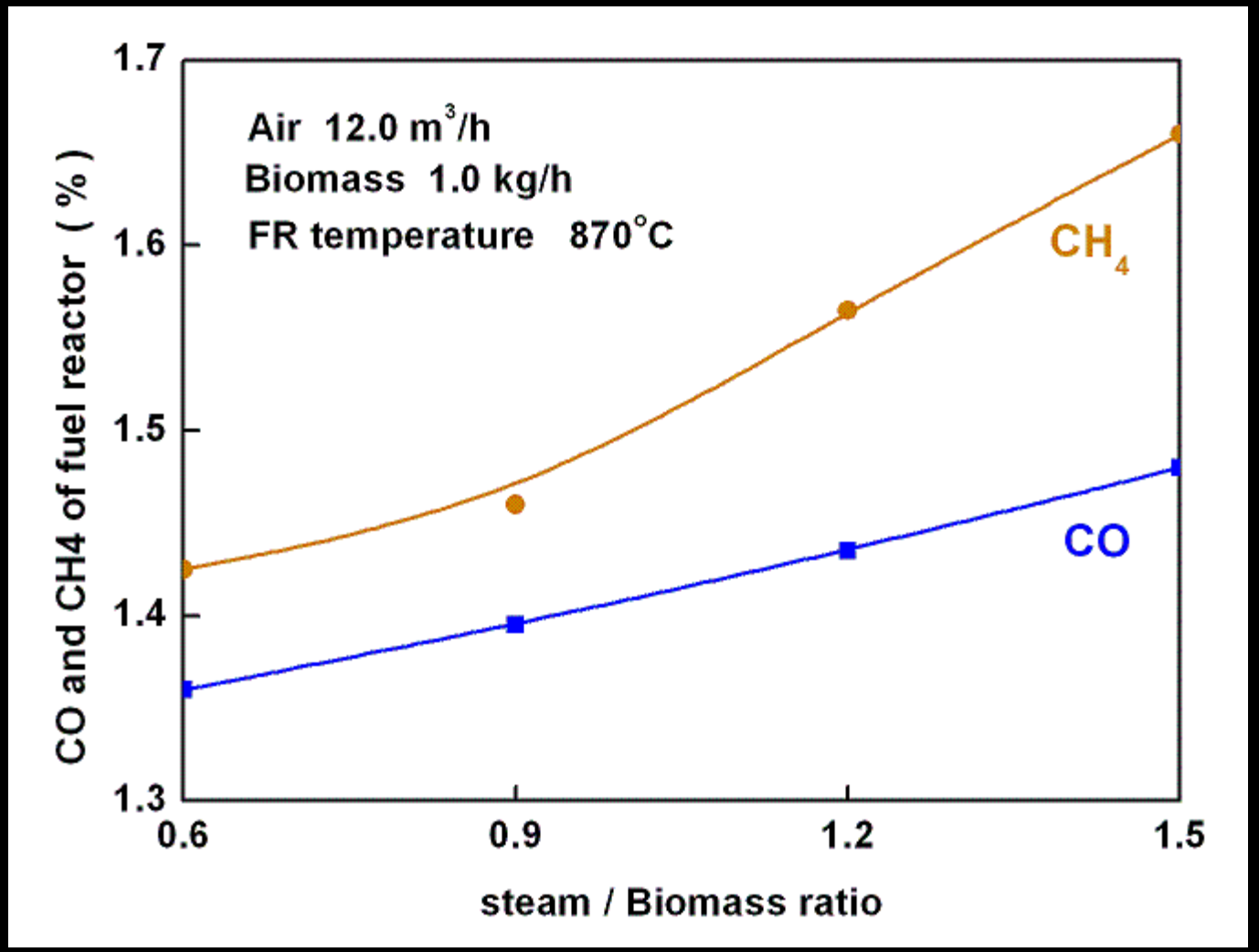

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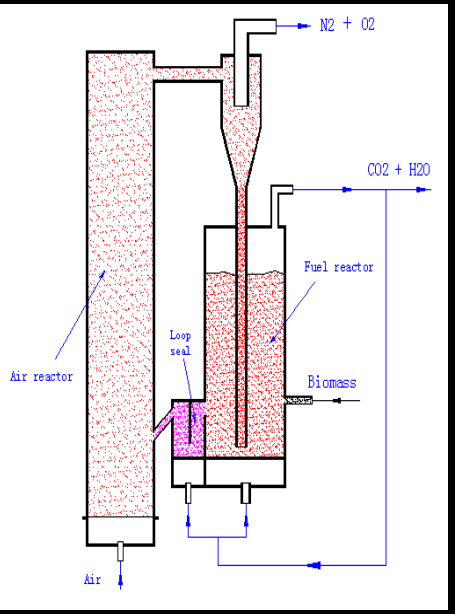
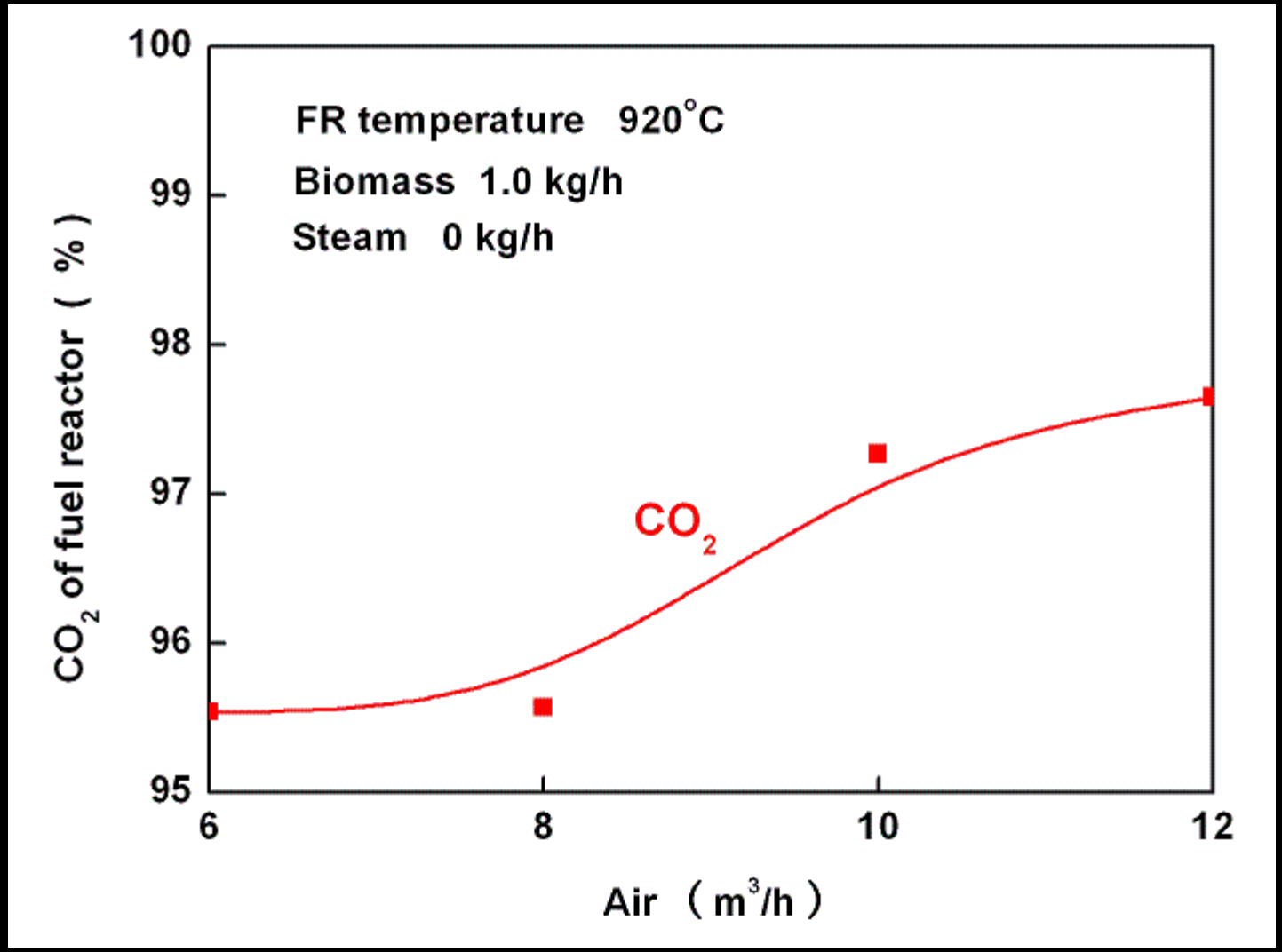
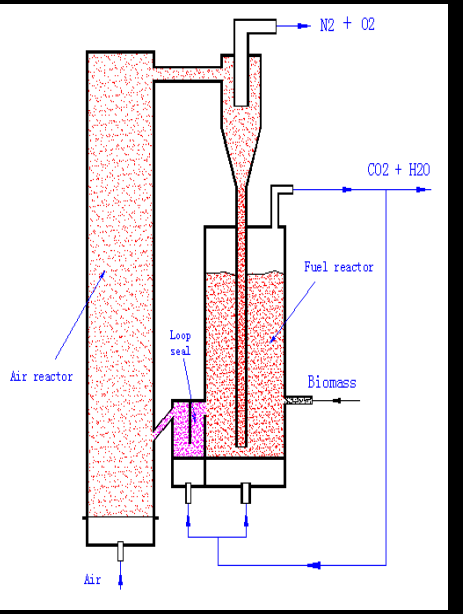


The height of air reactor in the present setup is not high enough for Ni oxidization with air.



Effect of air flow of air reactor

Experiments on chemical looping combustion of biomass



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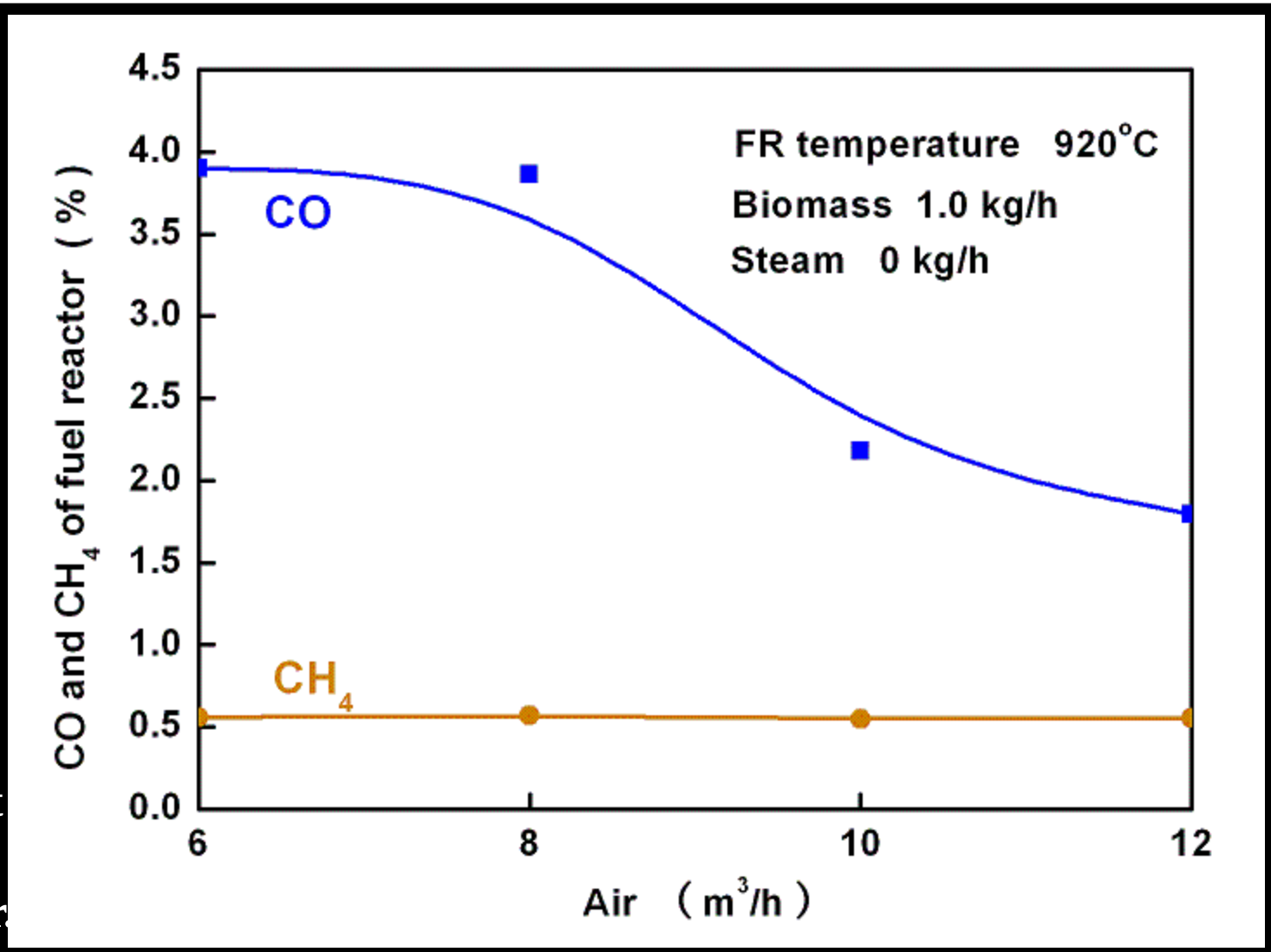

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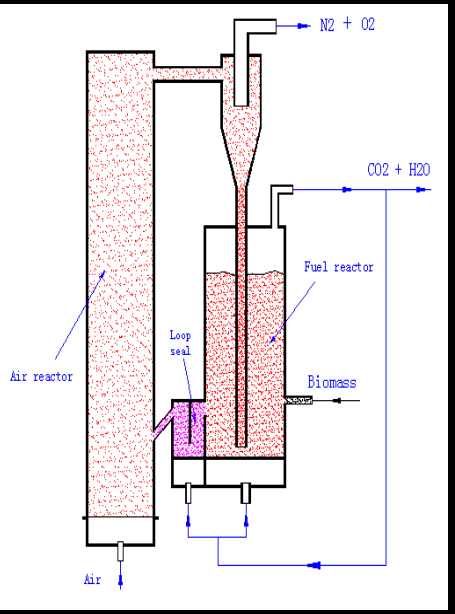

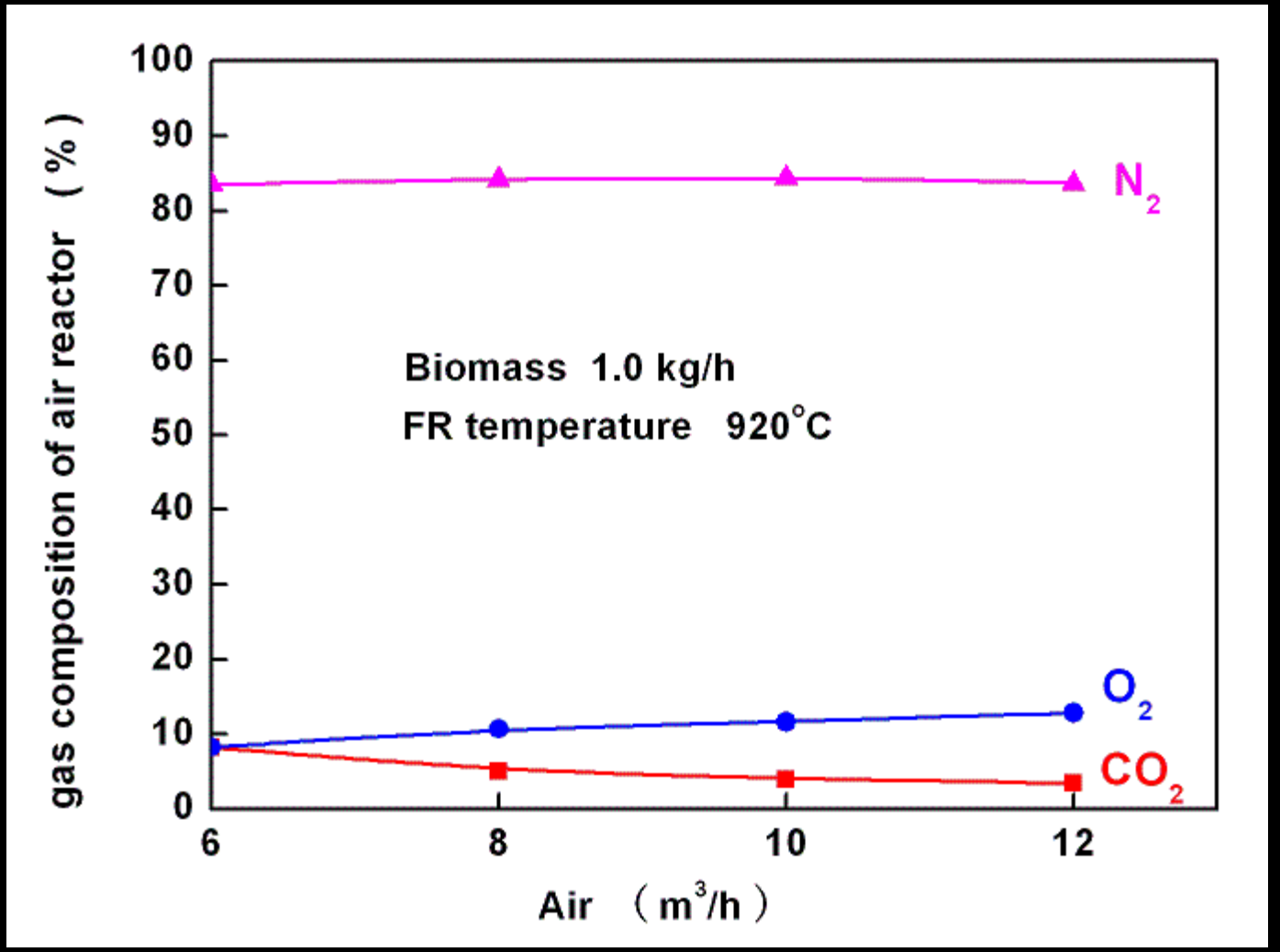

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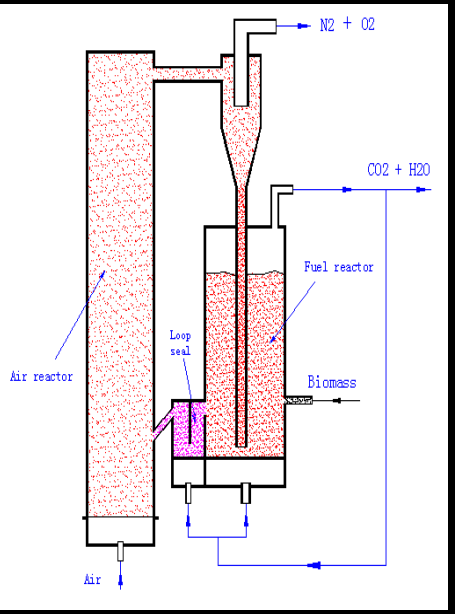
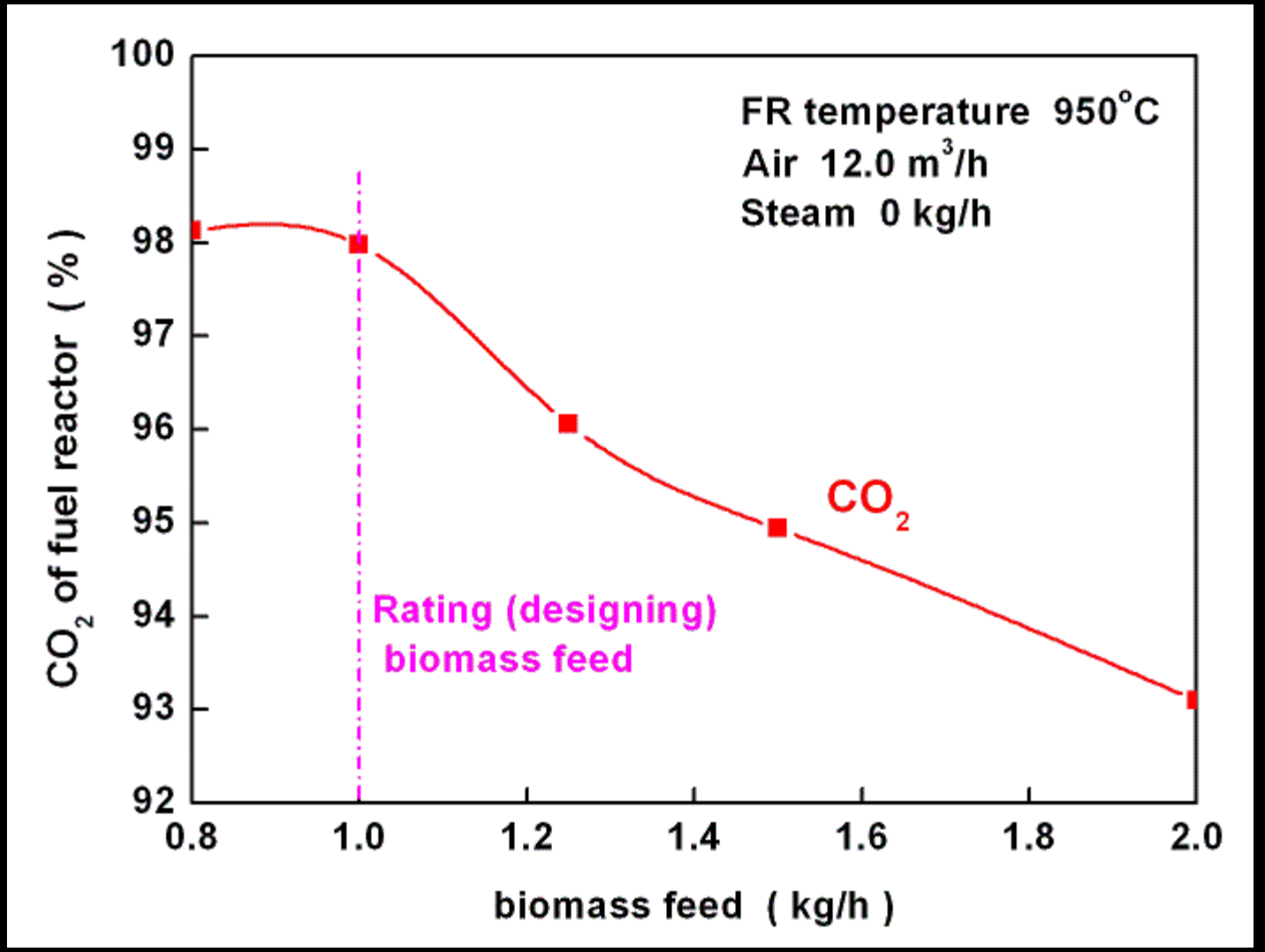
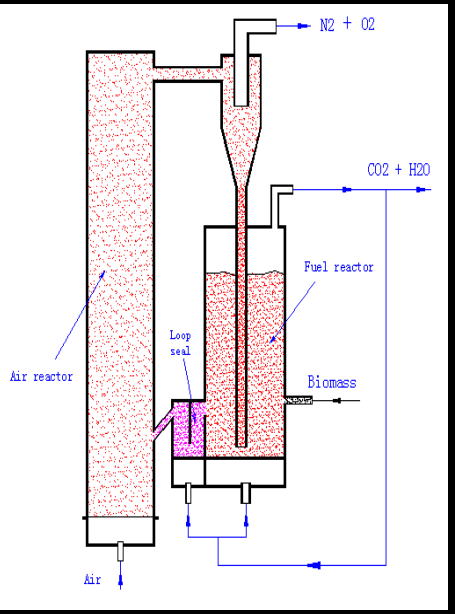
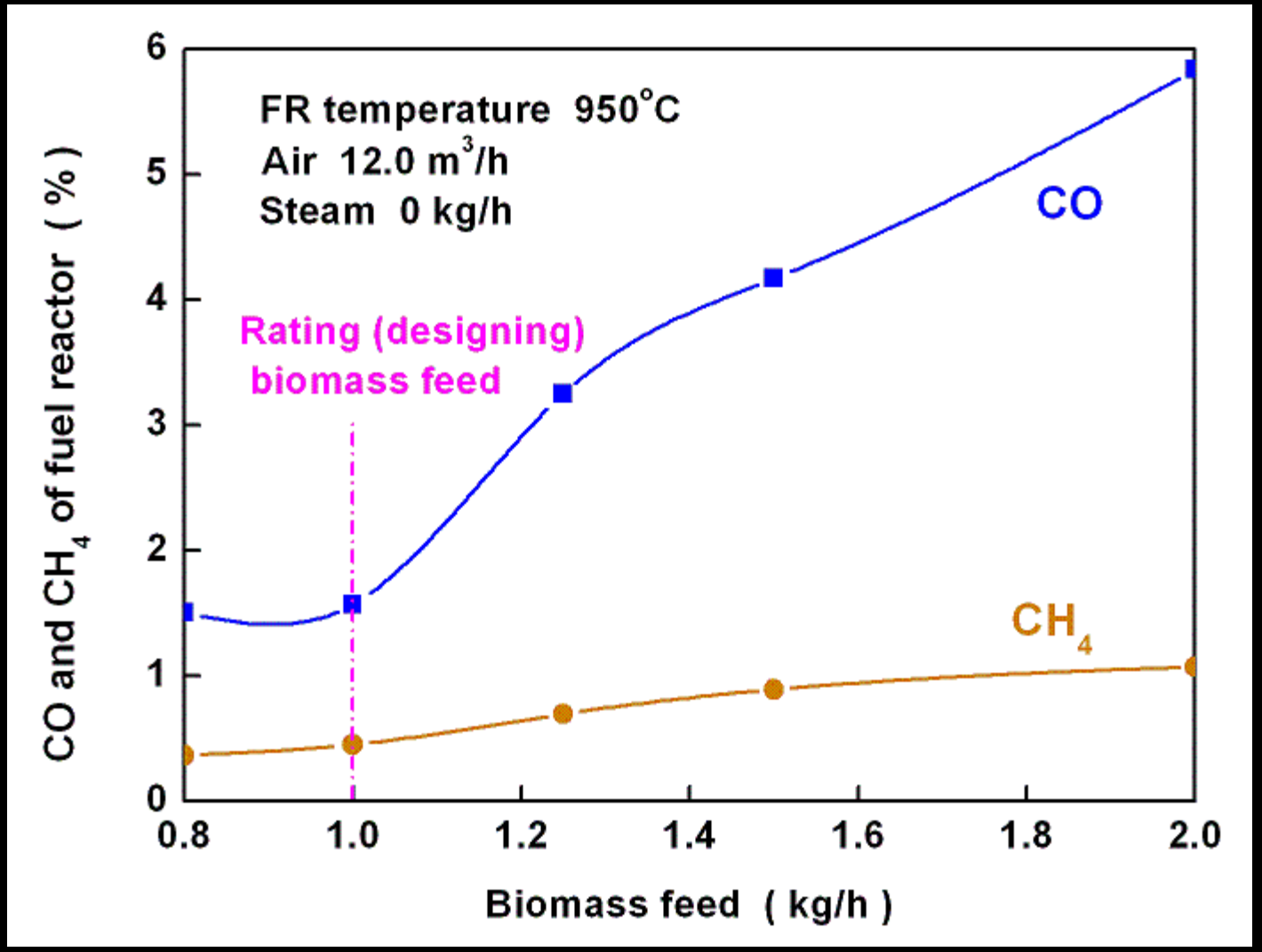




Effect of biomass feed

Experiments on chemical looping combustion of biomass





Effect of biomass feed

Conclusions

1. **The studies have being undertaken for 200 hours, and the results indicate that CLC of biomass is a feasible process for CO_2 separation, but more work is needed to optimise the process layout and to develop oxygen carriers.**
2. **A next step should be the construction of a pilot plant, which should be financed.**

Thank You

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